# Assessing the Environmental Effects on Dengue Fever and Malaysian Economic Growth

Chuie-Hong Tan, See-Nie Lee, and Sin-Ban Ho

***Abstract*—Environmental degradation is prone to increase severe weather conditions, such as heat waves and prolonged rainfall. The purpose of the study is to examine the effect of climate factors (temperature, rainfall, rain days, humidity, sea level pressure), floods and extreme events like tropical storm, tornado, typhoon and strong wind on dengue fever cases and Malaysian economic growth in the period of year 2014-2020. A correlation test was used to find the relationship between the independent, dependent and moderating variables. The study was carried out using secondary monthly data. The results showed a significant correlation between the climate change, dengue fever cases and economic growth in Malaysia. Temperature, humidity, sea level pressure and rain fall revealed a positive correlation with dengue fever cases, while rainy days and floods showed negative correlations. Besides that, increase of temperature, humidity, sea level pressure and floods moderate with dengue fever cases significantly lead to a lower economic growth.**

***Index Terms*—Climate change, economic growth, environmental degradation, health.**

## I. Introduction

Climatic factors (such as heat and precipitation changes) may influence the periodic and geological distribution of dengue disease in the study area. As the threat of climate change becomes more prominent in all sectors, its shadow on health care, especially the rising incidence of dengue fever, is likely to prove deadly. A recent international study showed that the prevalence of spawning dengue fever increased with a heat increase of 1 degree Celsius (℃) [1]. We have observed temperature rises in Peninsular Malaysia and East Malaysia, which are -0.5℃ - 1.5℃ and 0.5℃ - 1.0℃ respectively in the past 40 years. It is expected that in the next 100 years, the temperature in Peninsular Malaysia will rise by 1.1℃ - 3.6℃, and the temperature in East Malaysia will rise by 1.0-3.5℃. Rainfall is also expected to decrease by 8.8-18.7 percent 30 years later [2].

Mordecai *et al*. [3] found that rising temperatures will expand the spread of vector-borne diseases. As the earth is getting hotter, mosquitoes will thrive beyond their current habitat, thereby changing the variants of diseases such as dengue fever, malaria, West Nile virus and chikungunya fever. Various mosquitoes are acclimatized to a certain temperature range just as they bring different diseases. The risk of malaria is highest at 25℃ (78 degrees Fahrenheit), while zika is most likely to develop at 29°C (84 degrees Fahrenheit).

Past studies have shown that climate variables demonstrate an essential part in the Malaysia's prevalence because it directly affects the carrier's activity, bite rate, life cycle and the vector's incubation period [2], [4], [5]. The Aedes mosquito's life cycle is largely affected by climate variables, such as temperature, relative humidity and gathered rainfall [2], [6]. On a global scale, this climate change has witnessed the increasing occurrence of Aedes albopictus in the northern hemisphere [6]. It is predicted that 50-60 percent of the world's population will be inflicted to these media within 100 years as compared to only 35 percent currently due to the degree of climate change [7].

Disease-carrying mosquitoes cause approximately 1 million deaths each year. Dengue fever is rapidly becoming the most pressing health problem in Malaysia. Dengue fever cases have increased nearly 10 times in the past decade. According to media reports [8], Malaysian Ministry of Health has reported 84,688 dengue fever cases in 2020, of which at least 118 dengue patients have died. Malaysia is a country with a tropical climate, which serves a fertile breeding ground for Aedes mosquitoes. Hence, there is an increase in the number of Aedes mosquitoes.

The vector-borne diseases may burden the country's cost expenditure, and hence affect the economy growth. Research and development costs involved the intervention programs cost for dengue disease and chikungunya. Other incurred cost such as government vector control programs which include using Bti for microbial control of mosquito larvae, fogging or space spraying insecticides, as well as public education initiatives known as ComBI (Communication for Behavioral Impact) or IEC (Information Education and Communication). Vector-borne diseases have detrimental effects on economic growth and education [9]. Besides that, it also reduces country's per capita income [10], [11], decreases the volume of foreign direct investment [12] and weakens country's gross domestic productivity (GDP) [13], [14].

The purpose of this study is to assess climate change and the impact of dengue disease on economic growth in Malaysia. In the first stage, the relationship between climate variables such as rainfall, temperature and relative humidity and dengue disease cases are investigated. The second stage would be to estimate whether dengue disease affect to country's economic growth under climate change hazard.

## II. Literature Review

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### A. *Dengue Disease*

In Malaysia, dengue infection is one of the most prevalent public health problems [15], [16]. The first reported dengue incident was in 1901, and it has transmitted throughout Malaysia [16].

According to the NHS 'Fit for Travel' website, it quotes:

"Dengue fever is widespread throughout the tropics and subtropics, occurring in more than 100 countries. Nearly 100 million clinical cases of dengue fever are thought to occur every year."

"Dengue is the second most commonly identified cause of fever in ill international travelers."

Dengue fever is found to be one of the main causes for the fever infection of returned travelers which may provoke new dengue outbreaks in dengue-endemic areas nowadays [17]. Dengue fever infection, especially among patients returning from Southeast Asia are caused by the pathogen from Aedes mosquitoes. The episode of dengue fever is higher than other travel-related diseases, like typhoid fever and vaccine-preventable hepatitis A.

### B. *The Impact of Climate Change on Dengue Disease*

Climate changes has been considered in developing dengue disease and has recently captured much attention in the scientific community [18]–[25]. Climate change had disrupted natural systems, thus provoked diseases to disseminate or emerge in spaces where they had not existed. The long-term influences of climate change may alter the natural ecosystems and their effects on waterborne pathogens.

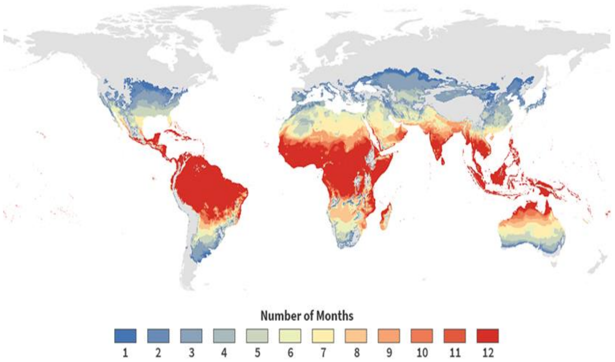


Fig. 1a. Current global circulation of the mosquito Aedes Aegypti – which may be contagious dengue fever, yellow fever, zika and chikungunya virus – by duration of time in each country.

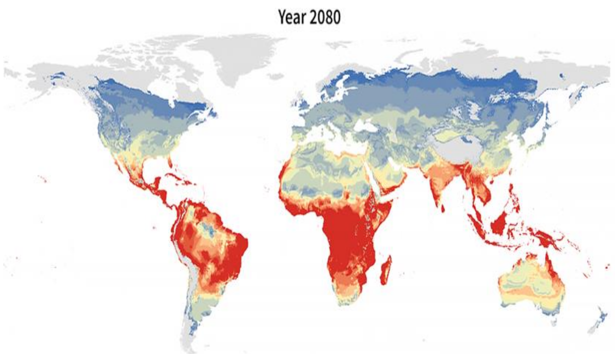


Fig. 1b. Forecasted region of the mosquito Aedes Aegypti in 2080 with consistent of worldwide greenhouse gas emissions.

Climate variables has been projected to raise the dengue models' predictive power [26]. Increased heat has been linked with dengue disease in tropical country [27]–[30]. Past research has discovered that rainfall exhibits a positive correlation with dengue cases [29], [31]. Several studies have revealed the relationship between climate variables and dengue cases in the past two decades. The use of climate variables as predictors in affecting the occurrence of dengue fever incidence has yet to be discovered and documented (Fig. 1a and Fig. 1b).

### C. *Economic Burden of a Dengue Disease*

Dengue disease embodies a significant economic burden to publics and health services in many hot and humid countries. In the past 30 years, studies show that there is a four-fold increase in the number of dengue cases [32]–[35].

It is reported that yearly economic burden of dengue disease of US$41.9 (±4.28 SE) million was estimated in Malaysia during period 2001-2005. The dengue costs included dengue illness expenses, vector control, as well as dengue-related government research and development, which contributed yearly costs of US$134 million in Malaysia [36].

The cost in dengue illness is significant and contributed to 3 percent – 7 percent of the government's health care expenditure. In Malaysia, the dengue illness costs are 11 times more than the expenditure on Aedes vector control [36]. It was found that an annual economic burden of dengue illness of US$56 million (Malaysian Ringgit 196 million) which is equivalent to US$2.03 (Malaysian Ringgit 7.14 million) per capital based on an adjusted estimate of total dengue cases [34].

The high dengue fever cases may increase government burden spending on healthcare facilities (healthcare professional, medicine, health worker, vaccine), healthcare facilities maintenance, vaccine development as well as dengue prevention, control and surveillance. Nevertheless, the cost of research and development for introducing healthcare policy and the operation of existing and new technologies will increase economic burden in Malaysia, and thus affect economic growth.

## III. Hypothesis Development

Climate changes will lead to common infectious endemic diseases such as dengue, cholera, malaria, Japanese encephalitis, leptospirosis, meningococcal meningitis and rickettsia infections.

Infectious diseases may cause economic growth to decline. The literature shows that there is a close connection between health and macroeconomics, because the health of the population can improve the economic situation by increasing labor productivity, education and investment levels, and demographic changes, thereby improving the country's economic outcomes. Diseases transmitted by climate change or foreign tourists may threaten the health of the domestic population, thereby reducing productivity and affecting economic growth.

Furthermore, the World Travel and Tourism Council estimates that after the SARS epidemic in China, Hong Kong, Vietnam, and Singapore, which was most severely affected, about 3 million people were unemployed in the tourism industry, causing losses of more than US$20 billion [37]. This may lead to the decrease on country's economic growth.

Nevertheless, the vector-borne diseases may bring burden of country's cost expenditure, such as healthcare facilities, facilities maintenance costs, cost of research and development for introducing health policy priorities, the cost of intervention program and the cost of government vector control program to mitigate chikungunya and dengue disease.

The following stated hypotheses tested for a clear understanding of the impact of dengue disease risk on Malaysian economic growth under climate change hazard.

H1: Climate change lead to dengue disease risk in Malaysia

H2: Climate change moderate the relationship between dengue disease risk and economic growth (GDP). The stronger (less) climate change leads to lower (higher) economy growth.

## IV. Methodology and Data

Volatility of surface air temperature, sea surface temperature, sea level, changes in Arctic sea ice and precipitation, and the occurrence of severe weather are usual parameters to record the climate change [38], [39]. However, changes in Arctic sea ice have become irrelevant in tropical countries such as Malaysia.

In this study, heat temperature and sea level data at designated locations are gathered. A weather station captures the climate change trend in the main areas of Peninsular Malaysia and Borneo, Malaysia. In every major region of Malaysia, at least one station with comprehensive climate data is selected. Part of the weather stations are located in the cities Kota Kinabalu and Kuching to capture climate change in Sabah and Sarawak respectively. In Peninsular Malaysia, the selected sites are Malacca (west coast), Kuantan (east coast) and Subang/Kuala Lumpur. GRETL software is employed to analyse the effect of climate change on dengue fever cases by using panel data. Furthermore, E-views software is used to run the time series data investigating the effect of dengue fever on economic growth under climate change condition.

### A. Mean Daily Temperature

Fig. 2a shows that from January 2014 to September 2020, in Kota Kinabalu, the annual moving average of mean daily temperature was on an upward trend, shifting between 25.7 ℃ and 29.6 ℃. Similar trends were detected in other stations. The temperature change ranges from 25.4 ℃ to 28.9 ℃ in Kuching, from 26.1 ℃ to 29.6 ℃ in Malacca, from 24.9 ℃ to 28.6 ℃ in Kuantan and between 26.5 ℃ to 29.7 ℃ in Kuala Lumpur/Subang. The degree of increase in the annual moving average of mean daily temperature was lowest for Kuantan, then followed by Kuching, Kota Kinabalu, Malacca and Kuala Lumpur/Subang in increasing order, as shown by the linear trendline gradient (Fig. 2a). The reported approximate rate of mean temperature increase was about 0.25 ℃, 0.20 ℃ and 0.14 ℃ per decade in Peninsular Malaysia, Sabah and Sarawak respectively [40]. El Nino phenomena has caused the temperature spikes in the period of 2015–2016 (see Fig. 2a, 2b, 2c and 2d). In the past 45 years, the frequency of El Niño has become more pronounced [41].

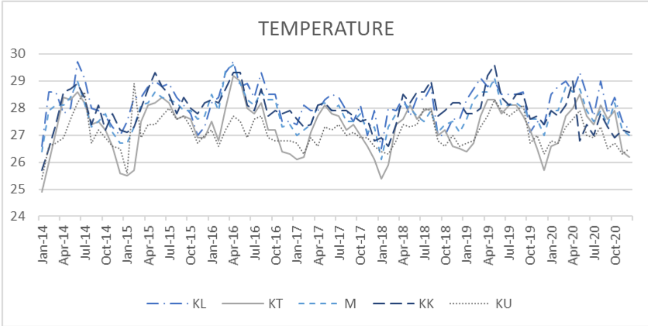


Fig. 2a. Monthly moving average of mean daily temperature in Kuala Lumpur/ Subang (KL), Kuantan (KT), Malacca (M), Kota Kinabalu (KK) and Kuching (KU).

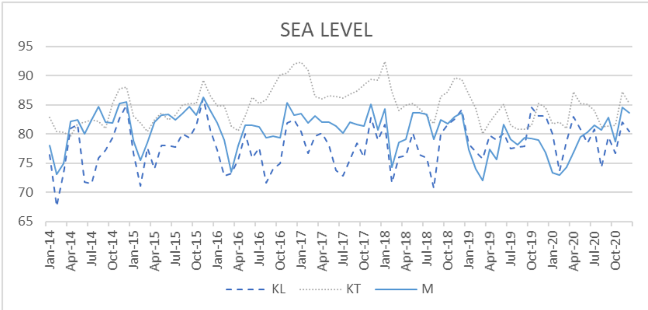


Fig. 2b. Monthly moving average of mean daily sea level in Kuala Lumpur/ Subang (KL), Kuantan (KT), Malacca (M), Kota Kinabalu (KK) and Kuching (KU).

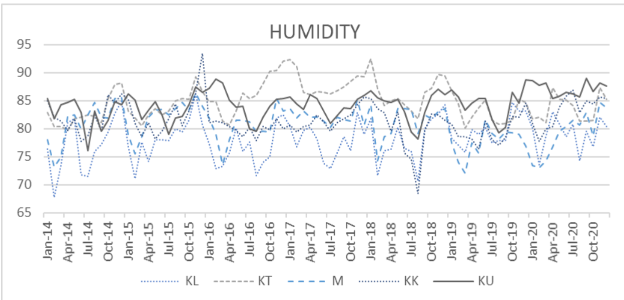


Fig. 2c. Monthly moving average of mean daily humidity in Kuala Lumpur/ Subang (KL), Kuantan (KT), Malacca (M), Kota Kinabalu (KK) and Kuching (KU).

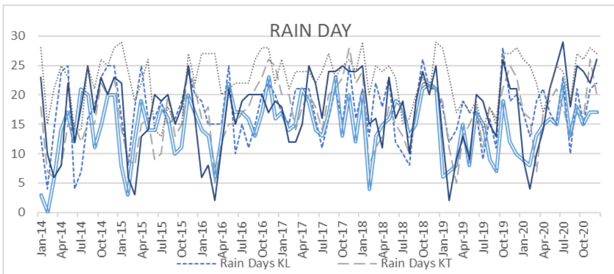


Fig. 2d. Monthly moving average of mean daily rain day in Kuala Lumpur/ Subang (KL), Kuantan (KT), Malacca (M), Kota Kinabalu (KK) and Kuching (KU).

Source: Tutiempo Network [42]

### B. Extreme Weather

Severe climate incidence in Malaysia are considered by high temperature, high rainfall, drought, strong winds and thunderstorm. Acute weather incidences have numerously recorded recently. During the 2006/2007 monsoon, the worst flooding occurred in the southern part of Peninsular Malaysia. Since the 1980s, the days of extreme rainfall events have been increasing. According to Sammathuria and Ling [41], the number of yearly thunderstorm days and strong wind days have increasingly occurred. Under the influence of El-Nino, the temperature surge in Fig. 2a, 2b, 2c and 2d clearly demonstrates the increase in high-temperature years [43]. Khor [44] discovered that the happening of drought and heavy rainfall is an emerging annual climate trend in Malaysia. Table I and Table II depict the growing histories of flood and severe weather incidence in Malaysia.

TABLE I: THE INCIDENCE OF MAJOR FLOODS IN MALAYSIA

| Date | Area | Detail |
|---|---|---|
| Jan 1971 | Kuala Lumpur, Malaysia | Since year 1926, heavy monsoon rains and flood resulted in 32 deaths and affected 180,000 victims. |
| Dec 2006 - Jan 2007 | Southeast Asian | Flash flood hit Johor severely and to a lower degree, Negeri Sembilan, Malacca and Pahang due to Typhoon Utor and heavy rainfall, |
| Jun 2007 | Kuala Lumpur, Malaysia | Since 10 June 2003, the flash flood hit Kuala Lumpur. |
| Dec 2007 | Certain regions of East Coast of Peninsula | The flash flood hit the states of Terengganu, Johor, Pahang and Kelantan in Malaysia. |
| Oct - Nov 2010 | North Malaysia and Thailand | Due to the La Nina monsoon rainfall a late monsoon occurs from Bengal Bay. The flood hit several areas in Malaysia and Thailand. The flood killed 232 people in Thailand and 4 deaths in Malaysia. |
| Jan - Feb 2014 | Sabah, Malaysia | Flash flood affected various areas of Sabah including Penampang, Tuaran and Menggatal due to torrential rainfall. |
| Dec 2014 - Jan 2015 | Southeast Asia and South Asia | Floods hit Sri Lanka, West Malaysia, Indonesia, and South Thailand due to the northeast monsoon, involving more than 417,000 victims. |
| Jan - Feb 2015 | East Malaysia | Due to intensified northeast monsoon, many areas of Sabah and Sarawak were hit by flooding, affecting 13,878 citizens. |
| Feb - Mar 2016 | Malaysia | Due to heavy rainfall, floods occurred in Johor, Sarawak, Malacca and regions of Negeri Sembilan. |
| Dec 2016 - early of 2017 | Southern Thailand | The annual monsoon season at Southern Thailand brought flash flood in Kelantan and Terengganu. It costed to an approximated loss of USD 4 billion, particularly cost on infrastructure, tourism and agriculture. |
| Nov 2017 | Penang, Malaysia | The worst in the state of Penang, Malaysia was resulted from tropical cyclone [45]. Around 3000 people was forced to evacuate due to flash flood after hours of torrential rain. |
| Jan 2018 | Malaysia | Due to the annual northeast monsoon which led to heavy rain, Terengganu, Johor, Pahang and Sabah were badly affected by floods. The flood killed 2 people in Pahang and affected around 12,000 victims [46]. |
| Oct 2019 | Malaysia | Storm and flood hit Selangor, Perak, Johor, Penang, Kedah, Perlis. It has affected 2,371 people from 657 families. |
| Nov 2019 | Malaysia | The flash flood hit Johor, Kelantan, Pahang and Terengganu. The flood killed 2 dead and bringing15,000 people displaced as floods worsen in Kelantan and Terengganu. |
| Nov 2020 - Early of 2021 | Malaysia | Pahang and Johor are badly affected by the flood this round. Terengganu, Kelantan, Selangor and Perak are also involved. In Sabah, flood happened in Beaufort. The flood has affected 8,000 people to evacuate their homes. Continuous heavy pours for several days due to the Northeast Monsoon Winds hit across Peninsular Malaysia |

TABLE II: OTHER SEVERE CLIMATE INCIDENCE IN MALAYSIA

| Date | Area | Detail |
|---|---|---|
| 26 December 2001 | Eastern Peninsular Malaysia | Tropical Storm Vamei from South China Sea brought landslides and flash flood to the eastern Peninsular Malaysia. |
| October - November 2014 | Peninsular Malaysia | The EF3 tornado incident that happened for 10-15 minutes with wind velocity to 240 km/h hit the states of Kedah and Selangor. In 2010, the frequent tornado incidents in Perlis, Penang and Selangor were due to changes in monsoon season. |
| October 2017 | Sabah, Malaysia | Typhoon Paolo which was formed by a tropical cyclone landed on Sabah, causing strong wind and torrential rain throughout the state. Damages were reported. |
| December 2017 | Malaysian Borneo | Strong winds crossed the west coast of Sabah, Labuan and Sarawak at a velocity of 40–50 km/h due to storm Kai Tak originated from western Pacific Ocean. |
| February 2018 | Penang, Malaysia | In Penang, a small tornado was reported and has damaged the building roof. |

## C. Rainfall and Rain Day

Periodic rainfall data depicts high variability which shared similar results from other research findings [41], [43], [47]. Fig. 3d shows the monthly rainfall of Kota Kinabalu reached a peak of 635.24 mm in December 2010. In Kuantan, the monthly rainfall peaked at the end of year 2014, 1818.9 mm (Fig. 3b). The observed data in Kuching (Fig. 3e) and Subang (Figure 3a) show that the rainfall peaked in February 2016 and October 2019, respectively. In other regions, August 2017 and June 2019 had the highest rainfall, but the yearly rainfall peaks were significant, especially in Malacca (Fig. 3c) and Kota Kinabalu (Fig. 3d). The figure also shows changes in monthly rainfall. Fig. 3 shows the average monthly rainfall in Malaysia. The annual upsurge in rainfall is due to the northeast monsoon, which is characterized by strong north easterly and easterly winds from the South China Sea during November until February, thus cascading the wet season to the area [48]. Rahman *et al*. [49] found that higher annual precipitation by the La Nina incidents whereby the temperatures of sea surface in the east central Equatorial Pacific fall below average. Fig. 3a–e depicts that higher average rainfall is connected with increasing number of rainy days, on the whole.

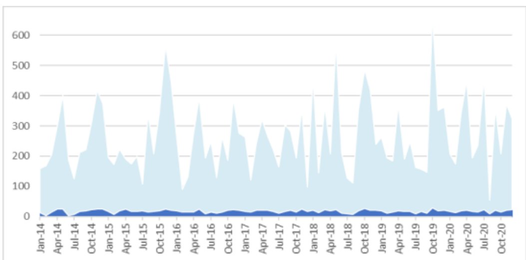

Fig. 3a. Average monthly precipitation and rainy days in Kuala Lumpur/Subang (KL).

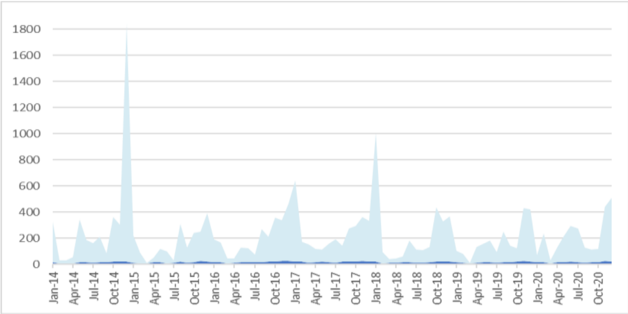


Fig. 3b. Average monthly precipitation and rainy days in Kuantan (KT).

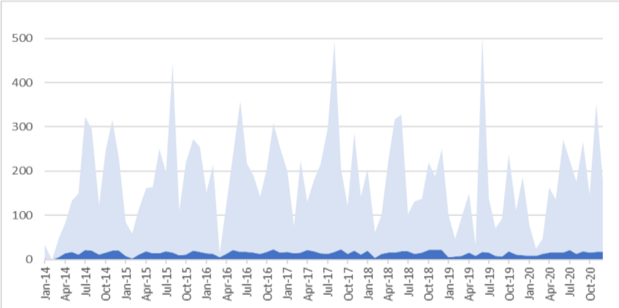


Fig. 3c. Average monthly precipitation and rainy days in Malacca (M).

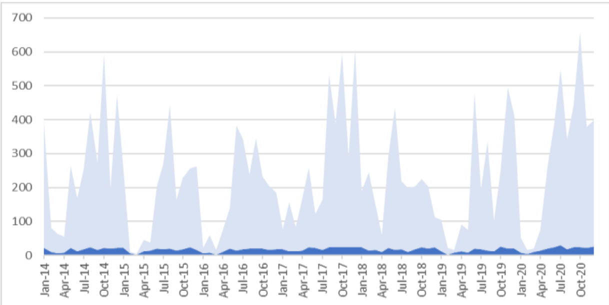


Fig. 3d. Average monthly precipitation and rainy days in Kota Kinabalu (KK).

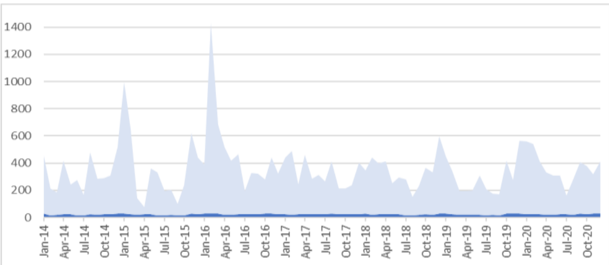


Fig. 3e. Average monthly precipitation and rainy days in Kuching (KU).

The collected data was analyzed using simple regression analysis. This study utilizes seven years of monthly data starting from January 2014 to December 2020. For the analysis testing the first hypothesis, the variables included in this study are dengue illness cases in Malaysia as the dependent variable, and climate variables, which are temperature, rainfall and humidity in Malaysia, as independent variables. In the second hypothesis testing, variable country's gross domestic productivity (GDP) is used as the dependent variable while variable dengue disease is the moderating variable.

Each dengue fever case reported in Malaysia between 2014 and 2020 was collected from National Crisis Preparedness and Response Centre (CPRC), Ministry of Health Malaysia (MOH). In addition, past studies linked to future climate change predictions, especially average temperature, average rainfall, and average sea level, was analyzed to test the consistency of such predictions. Climate change data such as temperature, rainfall and humidity data were collected from the Tutiempo Network. The instruments used to measure the independent variables were a thermometer for temperature, tipping for rainfall index and hygrometer for humidity. The yearly gross domestic productivity (GDP) collected data from the World Bank was then converted into average monthly data.

*Model*

The model considered in this study can be defined as:

$$LnDF_{it} = \beta_0 + \beta_1 LnTemp_{it} + \beta_2 LnSeaLevel_{it} + \beta_3 LnHumidity_{it} + \beta_4 LnRainFall_{it} + \beta_5 LnRainDay_{it} + \beta_6 LnFloods_{it} + \beta_7 LnExtremeEvents_{it} + \varepsilon_{it} \text{ --------------------------(1)}$$

$$LnGDP_{it} = \beta_0 + \beta_1 LnDF_{it} + \beta_2 Ln(DF{*}Temp_{it}) + \beta_3 Ln(DF{*}SeaLevel_{it}) + \beta_4 Ln(Humidity_{it}) + \beta_5 Ln(DF{*}RainDay_{it}) + \beta_6 Ln(DF{*}Floods_{it}) + \beta_7 Ln(DF{*}ExtremeEvents_{it}) + \varepsilon_{it} \text{-----------------(2)}$$

The dependent variable GDP is the gross domestic productivity of Malaysia for the period 2014–2020. The explanatory variables are defined as follows: DF is the monthly dengue fever cases in Malaysia; SeaLevel is atmospheric pressure of sea level in hPa; Humidity is total average relative humidity in percentage; RainFall is total rain fall in mm; RainDay is total rain day in monthly; Temp is the average monthly temperature in ℃. All the climate data are collected in cities of Malaysia such as Kuala Lumpur/Subang, Malacca, Kuantan, Kuching and Kota Kinabalu. Floods and extreme events are the total day of floods and extreme events in average monthly.

## V. Empirical Results

The first hypothesis proposes that most of the estimates in Table III show a significant positive coefficient for the dengue fever. This implies that climate change in temperature, sea level pressure, humidity and rain fall lead to an increase in dengue fever cases in Malaysia. The estimates of the coefficient of average monthly temperature change on dengue disease are positively significant 2.642, 3.339 and 2.349 with a 1 percent and 5 percent level of significance, under Ordinary Least Square (OLS), Fixed-Effects (FE) and First Difference Generalised Method of Moments (FD-GMM) systems respectively. This implies that a 1 percent of climate change of temperature leads to an increase of 2.6 to 3.3 dengue fever cases in Malaysia. The estimates of the coefficient of average monthly sea level change on dengue disease are positively significant 180.061, 197.798 and 83.632 with a 1 percent level of significance, under the three selected models respectively. Nevertheless, the result reveals a positively significant of humidity 0.852 and 1.236 on dengue fever cases in Malaysia, at 10 percent (OLS) and 1 percent (FD-GMM) significant level respectively. Rain fall also reveals a positively significant on dengue fever cases. However, the estimate of the coefficient of rain days on dengue disease is negatively significant -0.012, 0.009 and -0.010 with a 10 percent and 5 percent level of significance, by OLS, FE and FD-GMM models respectively. Besides that, the result also shows that the increase of floods will lead to lower dengue fever cases in Malaysia.

TABLE III: EFFECT OF CLIMATE CHANGE ON DENGUE FEVER CASES

| Variables | OLS | FE | FD-GMM |
|---|---|---|---|
| *LOG(Temperature)* | 2.642** 0.854 | 3.339*** 0.466 | 2.349** 1.072 |
| *LOG(Sea Level Pressure)* | 183.061*** 16.390 | 197.798*** 10.786 | 83.632*** 26.747 |
| *LOG(Humidity)* | 0.852* 0.333 | −0.009 0.993 | 1.236*** 0.663 |
| *Rain Day* | −0.012** 0.003 | −0.009* 0.005 | −0.010** 0.005 |
| *LOG(Rain Fall)* | 0.051*** 0.011 | 0.0776*** 0.020 | 0.057** 0.029 |
| *Floods* | −0.343*** 0.008 | −0.341*** 0.011 | −0.184*** 0.070 |
| *Extreme Events* | −0.00206561 0.0386559 | 0.0184973 0.0257696 | 0.0565885 0.0443898 |
| *Constant* | −1269.98*** 117.127 | −1370.67*** 79.5377 | −587.523*** 187.270 |
| *Diagnostic tests* | | | |
| Wald test [p-values] | 8.933*** 0.000 | 1.882*** 0.000 | 264.945*** [0.0000] |
| AR(2) test [p-values] | | | 0.7847 [0.4326] |
| Hansen J-test [p-values] | | | 248.007*** [0.0000] |
| Observations | 250 | 250 | 250 |

Notes: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

OLS = Pooled Ordinary Least Squares, FE = Fixed Effect (within estimator), and FD-GMM = First Difference Generalised Method of Moments.

The second hypothesis proposes that an increase of dengue fever cases leads to lower Malaysian economic growth (GDP). In Table IV, the regression coefficient is 25.924 significant at 5 percent level. The result reveals that most of the estimates are consistent with the expected sign with a significant negative coefficient for the GDP. This implies that an increase of dengue fever cases under climate change condition leads to a lower economic growth in Malaysia. The regression coefficients of temperature moderate with dengue fever cases on GDP are -1.081 (Kuala Lumpur/Subang), -3.345 (Malacca) and -2.359 (Kuching) and are statistically significant at 10 percent and 1 percent level respectively.

The regression coefficient of sea level pressure moderated with dengue fever cases on GDP is -61.483(Kuala Lumpur/Subang) and is statistically significant at 10 percent. Besides that, in Kuantan and Kuching, humidity change moderates the relationship between dengue disease risk and economic growth (GDP). In other words, high humidity and a rise of dengue cases lead to higher economic growth. On the contrary, high humidity and a rise of dengue cases lead to a lower economic growth in Malacca and Kota Kinabalu as shown in Table IV.

Nevertheless, frequent floods and a rise of dengue fever cases lead to lower economic growth. On the other hand, rain days has no significant impact on economic growth in the selected five states.

TABLE IV: EFFECT OF DENGUE FEVER ON ECONOMIC GROWTH UNDER CLIMATE CHANGE CONDITION

| | Kuala Lumpur/ Subang | Kuantan | Malacca | Kota Kinabalu | Kuching |
|---|---|---|---|---|---|
| *LOG(DF*Temperature)* | **-1.081 (0.062)*** | 0.464 (0.242) | **-3.345 (0.000)***** | -0.286 (0.497) | **-2.359 (0.000)***** |
| *LOG(DF*Sea Level Pressure* | **-61.483 (0.090)*** | NIL | 15.690 (0.692) | NIL | 22.520 (0.380) |
| *LOG(DF*Humidity)* | 0.323 (0.128) | **0.528 (0.069)*** | **-1.749 (0.000)***** | **-0.486 (0.035)**** | **0.611 (0.015)**** |
| *LOG(DF*Rain Days)* | -0.042 (0.162) | 0.006 (0.881) | 1.46E-07 (0.397) | -0.001 (0.934) | 0.015 (0.549) |
| *LOG(DF)* | | | **25.924 (0.0167)**** | | |
| *DF*FLOODS* | | | **-5.15E-06 (0.004)***** | | |
| *DF*EXTREME_EVENTS* | | | 3.16E-06 (0.345) | | |
| *Constant* | | | **176.885 (0.0168)**** | | |
| R-Squared | | | 0.740632 | | |
| F-Statistic | | | 8.430608 | | |
| Observation | | | 84 | | |

Notes: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

DF is dengue fever cases

## VI. CONCLUSION

Past studies reveal that health and macroeconomics are strongly correlated. One country's economic growth are determined by good health in the nation, since higher level of labor productivity, investment and education accelerate economic wellbeing. A reduction of the average income per capital was estimated when the variable of dengue disease in Malaysia was included into the economic growth model. This study is the first to contribute an analysis of the impact of dengue disease on Malaysia economic growth. As expected, the result reveals that the number of dengue cases shows a negative linear economic effect on Malaysia's economic growth, under the hazard of climate change condition.

Recent climate changes play a significant role on the dengue incidence rate in Malaysia. Precipitation changes of the study areas are significantly related to the dengue incidence rates. Temperature, sea level, humidity and rain fall are significant predictors. This finding may initiate Malaysian government to search a viable solution for climate change adaptation policies. However, climate changes are just one of the associated factors of dengue incidence rates. For future studies, population and socioeconomic factors such as education, income, household waste management and domestic water uses can be considered as predictors.

The expected number of dengue cases obtained from the forecast model can be used to model the economic growth. Subsequently prevention and recovery policies can be planned based on the dengue outbreak and the extent of inflicted economic problem.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

Chuie-Hong Tan and See-Nie Lee conducted the research, analyzed the data and wrote the paper; Sin-Ban Ho improved and edited the paper; all authors had approved the final version.

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